Chapter 3. Results and Discussion

Pattern of Riparian Habitat and Land Use Changes in the Entire Study Area

Within the study area, 32,481 acres of soils that could potentially support riparian forest and scrub (riparian soils) have been identified, comprising 60% of the study area. This area can be interpreted as the maximum historical area of woody riparian, riverwash, and open water cover types. The herbaceous riparian and marsh category was not included because this cover type is assumed to occur mostly on finer-textured basin soils, with only a small part occurring on coarser-textured riparian soils. Because riparian soils have been deposited by the river since the end of the Pleistocene, these soils represent the entire area where the river has made coarse deposits over the last 10,000 years; the actual area occupied by riparian habitats at any point in time was most likely much smaller than the total area of riparian soils that is currently present.

Riparian soils associated with the mainstem of the San Joaquin River occupy 44,900 acres, including lands outside the study area. The study area itself includes only 72% of the riparian soils, indicating that prehistoric riparian habitats may have extended beyond the study area boundary.

The area of "bottom lands" mapped by Hall (1886) between Friant and the Merced River totaled 4,600 acres, and the area of "swamp and overflowed lands" totaled approximately 80,300 acres. The area of swamp and overflowed lands is much larger than the area of riparian soils, but the area of bottom lands is smaller than both the area of riparian soils and the area of riparian habitat mapped in 1937. Hall's (1886) swamp and overflowed lands should thus be interpreted as lands that probably included both riparian forest and scrub on riparian soils and marshes on basin soils. Hall's (1886) map cannot be used to identify with certainty the extent of woody riparian vegetation in 1886; rather, it gives a rough estimate of the combined area of marsh and riparian vegetation in the area.

Comparison of the planform of the river between years shows a remarkable stability, in contrast to other Central Valley rivers, where meanders migrate much more (e.g., the Sacramento River).

Changes in acreages of riparian habitat and land use categories from 1937 to 1993 are shown in Figure 3 and Table 5. Between 1937 and 1957, a decrease of 92% in herbaceous riparian and marsh vegetation occurred. Riparian scrub also declined by 38% during this period, but riparian forest showed a slight increase. The large decline in riparian, and especially marsh, habitat appears to have been caused primarily by

conversion of these lands to agricultural fields, although changes in hydrology resulting from Friant Dam operations, which began in 1944, probably also had an effect. Friant Dam has reduced high flows in winter and spring, but has caused an increase in flow during summer, compared to pre-dam conditions. These increased summer flows, combined with reduced flood disturbance, may have caused the increase in riparian forest found for 1957.

Between 1937 and 1993, riparian forest became more dense on average and riparian scrub became more open.

Because of the complexity of the combined effects of changes in land use, hydrology, and climate that differ between the study reaches, the overall pattern of changes in riparian habitat area for the entire study area after 1957 is complicated. After 1957, an increase in conversion of grassland and pasture as well as agricultural fields to orchards and vineyards and an increase in aggregate mining and urban development are apparent (Figure 3). Effects of aggregate mining are reflected in an increase in areas mapped as aggregate mines and areas mapped as open water.

Land use changes, mechanical clearing, and droughts have a negative effect on riparian vegetation, but they may be partially counteracted by riparian encroachment on sand and gravel bars caused by the reduction in scouring flows due to Friant Dam, or lowering of the water table due to other causes (e.g., groundwater pumping). The conversion of riparian scrub to forest observed during the 1980s is consistent with growth of developing riparian vegetation during uninterrupted vegetation succession. In particular, the increase in dense, mixed riparian forest in the 1980s would be consistent with the encroachment of willows or alders on former sand and gravel bars, as was observed by Peltzman (1973) and Cain (1997).

Because of the hydrologic and geomorphic differences in the study reaches, an analysis of riparian habitat and land use changes by reach is more meaningful than an analysis of these changes for the study area as a whole.

Riparian Habitat and Land Use Changes in Reach I: Friant Dam to Gravelly Ford

Riparian soils cover 10,118 acres of Reach 1 (66% of the total area). The area of woody riparian, riverwash, and open water cover types in Reach 1 in 1937 totaled 3,851 acres, indicating that by 1937, 38% of the riparian soil area supported riverine habitats.

Figure 4 and Table 6 show changes in the acreages of riparian habitat and land use types in Reach 1. From 1937 to 1957, grassland and pasture and herbaceous riparian and marsh cover types were converted to agricultural field, vineyard, and orchard cover types. The overall area of agricultural and disturbed lands during this period changed by less than 10%. The major changes affecting the conditions necessary for riparian habitat was the building of Friant Dam and increased aggregate mining. Because of its

Table 5
Acreage of Riparian Habitat and Land Use Types in the Study Area

	Year			
	1937	1957	1978	1993
Riparian habitat				
Open water	3,883	3,036	3,306	3,747
Riverwash	1,081	1,213	1,103	297
Riparian vegetation				
Riparian forest				
Cottonwood riparian forest	251	0	4	65
Cottonwood riparian forest - low density	283	0	61	146
Mixed riparian forest	641	956	864	1,242
Mixed riparian forest - low density	928	1,497	652	690
Valley oak riparian forest	108	88	128	549
Valley oak riparian forest - low density	28	140	155	58
Total riparian forest	2,240	2,681	1,864	2,750
Riparian scrub				
Riparian scrub	3,393	1,653	1,154	1,022
Riparian scrub - low density	1,153	1,167	1,940	1,142
Total riparian scrub	4,547	2,820	3,094	2,164
Herbaceous riparian	4,076	324	770	738
Total riparian vegetation	10,862	5,825	5,729	5,652
Total riparian habitat	15,825	10,074	10,136	9,695
Open space				
Grassland and pasture	19,480	14,505	11,509	12,180
Agricultural field	15,021	24,602	24,019	20,825
Orchard and vineyard	2,960	3,045	5,121	6,105
Disturbed land				
Former aggregate mining	110	70	142	57
Other	153	294	215	428
Total disturbed land	263	364	357	486
Total open space	37,725	42,516	41,006	39,596
Urban and industrial				
Aggregate mining	71	397	872	554
Other industrial	70	122	259	387
Urban/residential	159	774	1,412	1,640
Total urban and industrial	300	1,293	2,543	2,581
No data	33	0	199	2,011
Total	53,883	53,883	53,883	53,883

Note: Inconsistencies in totals are a result of rounding.

Table 6
Acreage of Riparian Habitat and Land Use Types in Reach I: Friant Dam to Gravelly Ford

	Year			
	1937	1957	1978	1993
Riparian habitat				
Open water	1,717	1,070	1,250	1,766
Riverwash	291	94	16	2
Riparian vegetation				
Riparian forest				
Cottonwood riparian forest	236	0	0	40
Cottonwood riparian forest - low density	77	0	0	7
Mixed riparian forest	91	225	248	547
Mixed riparian forest - low density	66	578	116	265
Valley oak riparian forest	55	88	128	537
Valley oak riparian forest - low density	28	140	155	58
Total riparian forest	553	1,031	646	1,453
Riparian scrub				
Riparian scrub	1,205	782	386	362
Riparian scrub - low density	85	551	847	254
Total riparian scrub	1,290	1,334	1,233	616
Herbaceous riparian	394	78	48	0
Total riparian vegetation	2,237	2,443	1,927	2,070
Total riparian habitat	4,245	3,607	3,193	3,838
Open space				
Grassland and pasture	3,193	2,412	2,272	3,686
Agricultural field	4,790	5,252	2,888	1,723
Orchard and vineyard	2,686	2,994	4,741	3,878
Disturbed land				
Former aggregate mining	110	0	142	57
Other	67	294	156	235
Total disturbed land	177	294	297	292
Total open space	10,847	10,952	10,199	9,580
Urban and industrial				
Aggregate mining	71	397	872	554
Other industrial	24	71	133	292
Urban/residential	74	235	800	997
Total urban and industrial	170	703	1,805	1,843
No data	0	0	65	0
Total	15,262	15,262	15,262	15,262

Note: Inconsistencies in totals are a result of rounding.

proximity to the dam, Reach 1 is most affected by the dam. The extent of areas mapped as exposed gravel bars and open water declined and the area of riparian forest increased, probably because of the encroachment of riparian vegetation on the channel. Cottonwood forest converted to mixed riparian forest, probably because of an increase in willows, alders and other species, which are particularly good colonizers following upstream diversions (Peltzman 1973).

After 1957, the area of orchard and vineyard, aggregate mining, and urban development land uses increased at the expense of agricultural row crops. Riparian scrub tended to decrease while riparian forest tended to increase, probably as a result of ecological succession that is not periodically interrupted by the scouring floods that occurred before the dam was built, or as the result of lowering of the water table from other causes. Gravel bars, herbaceous riparian habitat, and marsh continued to decline after 1957.

Locations of representative subreaches are shown in Figure 5. Figures 6 and 7 illustrate the changes in land use and the transition from herbaceous riparian and scrub cover types to mature riparian forest.

Riparian Habitat and Land Use Changes in Reach 2: Gravelly Ford to Mendota Pool

Riparian soils are present on 5,639 acres (60%) of Reach 2. The area of woody riparian, riverwash, and open water cover types in Reach 2 in 1937 totaled 3,150 acres (Table 7), indicating that by 1937, 56% of the riparian soil area supported riverine habitats.

Figure 8 and Table 7 show that the agricultural field cover type increased dramatically between 1937 and 1957. Riparian scrub, forest, and herbaceous and marsh cover types strongly declined; agricultural conversion is apparently the primary cause of the decline. Differences in open water and riverwash cover types among the four years (1937, 1957, 1978, and 1993) was mainly caused by differences in river stage, which were due to differences in the time of year the aerial photographs were taken.

After 1957, agricultural fields were increasingly converted to vineyards. Riparian forest and scrub continued their downward trend, although there was a slight increase in forest in the 1980s, probably as a result of succession from scrub to forest. Herbaceous riparian habitat shows an increase in 1978 because of temporarily high flows in the river, perhaps as the result of high precipitation in 1978.

Figures 9 and 10 illustrate the changes in land use and the transition from herbaceous riparian habitat and scrub to mature riparian forest.

Riparian Habitat and Land Use Changes in Reach 3: Mendota Pool to Sack Dam

Riparian soils occur on 5,331 acres (63%) of Reach 3. The area of woody riparian, riverwash, and open water cover types in Reach 3 in 1937 totaled 1,598 acres (Table 8), indicating that by 1937, 30% of the riparian soil area supported riverine habitats.

Figure 11 and Table 8 show changes in acreages of riparian habitat and land use types in Reach 3. Between 1937 and 1957, a large portion of grassland and pasture and riparian scrub cover types were converted to agricultural fields, which increased by 32%. Riverwash and herbaceous riparian and marsh cover types also declined over this period.

Since 1957, there has been little change in the area of riparian scrub, but riparian forest has increased while riverwash has strongly declined. The riparian vegetation apparently colonized sand and gravel bars and encroached on the channel after the completion of the Delta-Mendota canal and resulting higher summer flows. The forest consists almost exclusively of mixed riparian forest, which includes rapidly colonizing willow species. As in Reach 2, a temporary increase in herbaceous riparian habitat and marsh is observed, perhaps because of high precipitation in 1978. Like for Reach 2, the change in the area of open water mainly reflects the stage (water elevation) of the river during which the aerial photographs were taken.

Figures 12 and 13 illustrate the increase in urban and agricultural development and the decrease in riverwash (i.e., exposed sand and gravel bars) and riparian scrub habitats over time in Reach 3. The figures also show the increase in mixed riparian forest.

Riparian Habitat and Land Use Changes in Reach 4: Sack Dam to Bear Creek

Riparian soils occur on 7,915 acres (61%) of Reach 4. The total area of woody riparian, riverwash, and open water cover types in Reach 4 in 1937 was 1,881 acres (Table 9), indicating that by 1937, 24% of the riparian soil area supported riverine habitats.

Between 1937 and 1957, the area of the agricultural field cover type more than doubled in Reach 4 (Table 9, Figure 14). Grassland and pasture decreased by 35% and the herbaceous riparian and marsh cover type decreased by 84% during that period. Riparian forest and scrub also decreased in area.

After 1957, the area of the agricultural field cover type continued to increase as a result of conversion of grassland and pasture, albeit at a slower rate. The area of

Table 7
Acreage of Riparian Habitat and Land Use Types in Reach 2: Gravelly Ford to Mendota Dam

	Year			
	1937	1957	1978	1993
Riparian habitat				
Open water	976	289	283	747
Riverwash	157	629	836	234
Riparian vegetation				
Riparian forest				
Cottonwood riparian forest	0	0	4	0
Cottonwood riparian forest - low density	0	0	0	0
Mixed riparian forest	223	282	35	100
Mixed riparian forest - low density	284	50	0	59
Valley oak riparian forest	13	0	0	0
Valley oak riparian forest - low density	0	0	0	0
Total riparian forest	521	332	39	158
Riparian scrub				
Riparian scrub	1,279	387	147	45
Riparian scrub - low density	217	205	124	26
Total riparian scrub	1,496	592	272	71
Herbaceous riparian	1,375	2	218	53
Total riparian vegetation	3,392	926	529	283
Total riparian habitat	4,525	1,844	1,647	1,264
Open space				
Grassland and pasture	3,499	2,489	1,749	1,143
Agricultural field	1,264	5,228	5,792	3,609
Orchard and vineyard	274	0	237	2,199
Disturbed land				
Former aggregate mining	0	0	0	0
Other	0	0	0	0
Total disturbed land	0	0	0	0
Total open space	5,036	7,717	7,778	6,951
Urban and industrial				
Aggregate mining	0	0	0	0
Other industrial	0	0	0	0
Urban/residential	0	0	3	4
Total urban and industrial	0	0	3	4
No data	0	0	133	1,341
Total	9,561	9,561	9,561	9,561

Note: Inconsistencies in totals are a result of rounding.

Table 8
Acreage of Riparian Habitat and Land Use Types in Reach 3: Mendota Dam to Sack Dam

	Year			
	1937	1957	1978	1993
Riparian habitat				
Open water	350	480	626	495
Riverwash	336	254	53	4
Riparian vegetation				
Riparian forest				
Cottonwood riparian forest	0	0	0	15
Cottonwood riparian forest - low density	27	0	0	0
Mixed riparian forest	56	53	127	178
Mixed riparian forest - low density	74	0	136	103
Valley oak riparian forest	0	0	0	0
Valley oak riparian forest - low density	0	0	0	0
Total riparian forest	158	53	263	297
Riparian scrub				
Riparian scrub	467	127	99	55
Riparian scrub - low density	287	95	183	222
Total riparian scrub	754	222	283	276
Herbaceous riparian	19	4	45	7
Total riparian vegetation	931	279	591	580
Total riparian habitat	1,617	1,014	1,270	1,079
Open space				
Grassland and pasture	1,607	112	150	186
Agricultural field	4,984	6,595	6,184	6,076
Orchard and vineyard	0	50	81	28
Disturbed land				
Former aggregate mine	0	63	0	0
Other	86	0	30	144
Total disturbed land	86	63	30	144
Total open space	6,678	6,821	6,444	6,434
Urban and industrial				
Gravel mining	0	0	0	0
Other industrial	35	40	90	68
Urban/residential	85	539	609	640
Total urban and industrial	120	580	700	707
No data	0	0	0	194
Total	8,414	8,414	8,414	8,414

Note: Inconsistencies in totals are a result of rounding.

Table 9
Acreage of Riparian Habitat and Land Use Types in Reach 4: Sack Dam to Bear Creek

	Year			
	1937	1957	1978	1993
Riparian habitat				
Open water	449	759	773	368
Riverwash	246	141	168	54
Riparian vegetation				
Riparian forest				
Cottonwood riparian forest	15	0	0	0
Cottonwood riparian forest - low density	73	0	7	21
Mixed riparian forest	155	51	56	153
Mixed riparian forest - low density	150	265	84	67
Valley oak riparian forest	39	0	0	12
Valley oak riparian forest - low density	0	0	0	0
Total riparian forest	432	316	146	253
Riparian scrub				
Riparian scrub	371	277	207	485
Riparian scrub - low density	383	214	410	546
Total riparian scrub	754	491	617	1,032
Herbaceous riparian	1,162	191	338	618
Total riparian vegetation	2,348	998	1,101	1,902
Total riparian habitat	3,044	1,897	2,043	2,324
Open space				
Grassland and pasture	7,140	4,666	3,309	2,409
Agricultural field	2,729	6,343	7,488	8,023
Orchard and vineyard	0	0	61	0
Disturbed land				
Former aggregate mining	0	7	0	0
Other	0	0	0	5
Total disturbed land	0	7	0	5
Total open space	9,870	11,016	10,859	10,438
Urban and industrial				
Aggregate mining	0	0	0	0
Other industrial	10	10	22	16
Urban/residential	0	0	0	0
Total urban and industrial	10	10	22	16
No data	0	0	0	146
Total	12,924	12,923	12,924	12,923

Note: Inconsistencies in totals are a result of rounding.

herbaceous riparian and marsh cover type increased from 1957 to 1978 and again from 1978 to 1993 because of an increase in wetland area on the San Luis National Wildlife Refuge. Riparian scrub also increased, particularly after 1978. In large part, this increase was a result of increased riparian scrub acreage at the San Luis National Wildlife Refuge.

Figures 15 and 16 demonstrate how, on a typical reach of the river, grassland was converted to the agricultural field type and how the river has become confined between levees with a narrow strip of riparian trees.

Riparian Habitat and Land Use Change in Reach 5: Bear Creek to Merced River

Riparian soils are present on 3,478 acres (55%) of Reach 5. The total area of woody riparian, riverwash, and open water cover types in Reach 5 in 1937 was 1,271 acres (Table 10), indicating that by 1937, 37% of the riparian soils supported riverine habitats.

Between 1937 and 1957, a large decrease (96%) in the area of herbaceous riparian and marsh vegetation occurred (Figure 17, Table 10). Most of this area was drained and converted to grassland and pasture, and a part of this area converted to riparian forest. Lack of periodic floods and lowering of the water table made areas north of the San Joaquin River unsuitable for marsh and allowed establishment of riparian vegetation on the old natural levees that are abundant in this area.

Riparian forest in 1978 shows a decrease over 1957 levels, perhaps as a result of temporarily higher flows caused by the drought in the 1970s. After 1978, the area of riparian scrub decreased.

Figures 18 and 19 illustrate the transition from herbaceous riparian vegetation to mixed riparian forest that occurred in portions of Reach 5.

Table 10
Acreage of Riparian Habitat and Land Use Types in Reach 5: Bear Creek to Merced River

	Year			
	1937	1957	1978	1993
Riparian habitat				
Open water	391	438	374	371
Riverwash	51	95	29	2
Riparian vegetation				
Riparian forest				
Cottonwood riparian forest	0	0	0	10
Cottonwood riparian forest - low density	106	0	54	118
Mixed riparian forest	116	345	398	264
Mixed riparian forest - low density	354	604	317	196
Valley oak riparian forest	0	0	0	0
Valley oak riparian forest - low density	0	0	0	0
Total riparian forest	576	948	769	588
Riparian scrub				
Riparian scrub	72	80	316	75
Riparian scrub - low density	181	101	374	94
Total riparian scrub	253	181	690	168
Herbaceous riparian	1,125	50	121	60
Total riparian vegetation	1,953	1,179	1,580	817
Total riparian habitat	2,396	1,712	1,983	1,190
Open space				
Grassland and pasture	4,041	4,827	4,030	4,756
Agricultural field	1,254	1,184	1,667	1,392
Orchard and vineyard	0	0	0	0
Disturbed land				
Former aggregate mining	0	0	0	0
Other	0	0	30	45
Total disturbed land	0	0	30	45
Total open space	5,294	6,010	5,726	6,193
Urban and industrial				
Aggregate mining	0	0	0	0
Other industrial	0	0	14	10
Urban/residential	0	0	0	0
Total urban and industrial	0	0	14	10
No data	33	0	0	329
Total	7,723	7,723	7,723	7,723

Note: Inconsistencies in totals are a result of rounding.